



# MULTIFUNCTIONAL TOXIN DECONTAMINATION COATINGS

for Sustained Protection of People and the Environment

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# CURRENT TECHNOLOGIES AND LIMITATIONS

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## Physical Barrier Protection

- Selective Adsorption
  - Activated charcoal - HEPA system
- Impermeable Polymer Barriers



### Drawbacks:

- Contaminated barriers are hazardous and cause disposal problem
- Impermeable barriers cause heat and perspiration

## Active Protection

### Chemical Catalysis Approach

- Oxidants ( $\text{TiO}_2$ ) • Metal chelators • Engineered catalysts

**Drawbacks:** Catalysts destroy filter; Very slow, Not efficient

### Enzymatic Catalysis Approach

- Free enzyme in solution • Cross-linked to a substrate

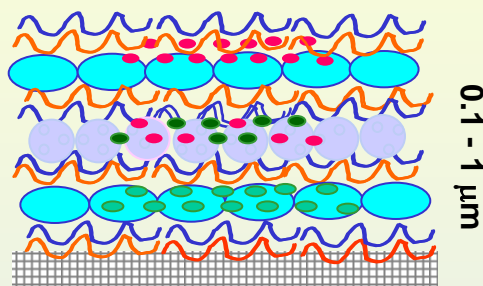
**Drawbacks:**

- Limited stability in working environment
- Loss of activity during processing

Our Approach Removes Most of these Limitations  
and  
Provides Additional Capabilities

# OUR APPROACH

## Enzyme Based Multifunctional Coatings

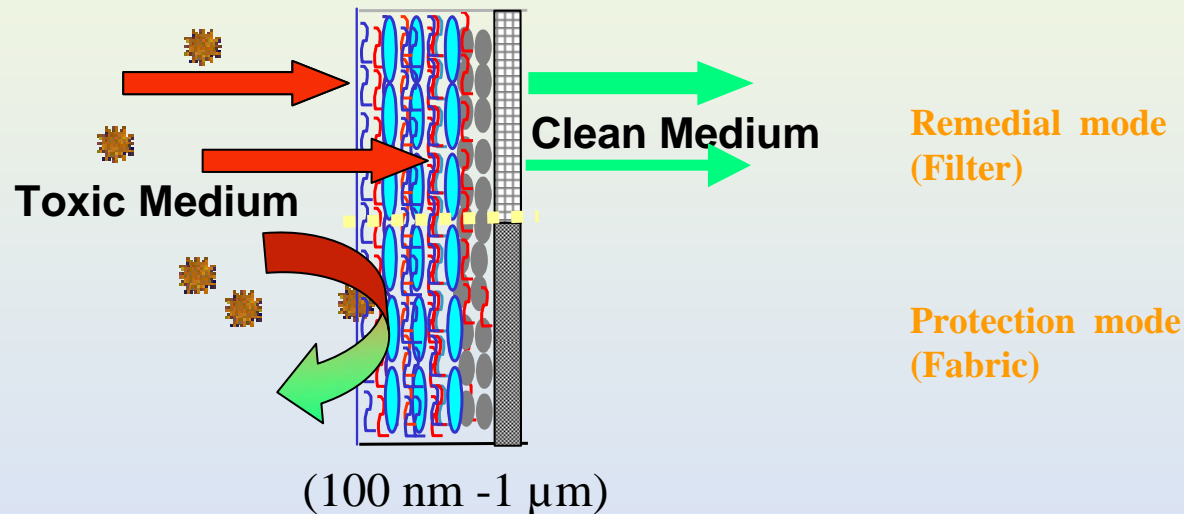


Incorporates advantages of enzymes by embedding them in multilayers, which leads to

- Stability
  - Sustained catalytic efficiency
  - Multifunctional capability
- 
- Light weight
  - Cost effective
  - Hazmat-free
  - Reusable

# MULTIFUNCTIONAL SELF-CLEANING FILTERS

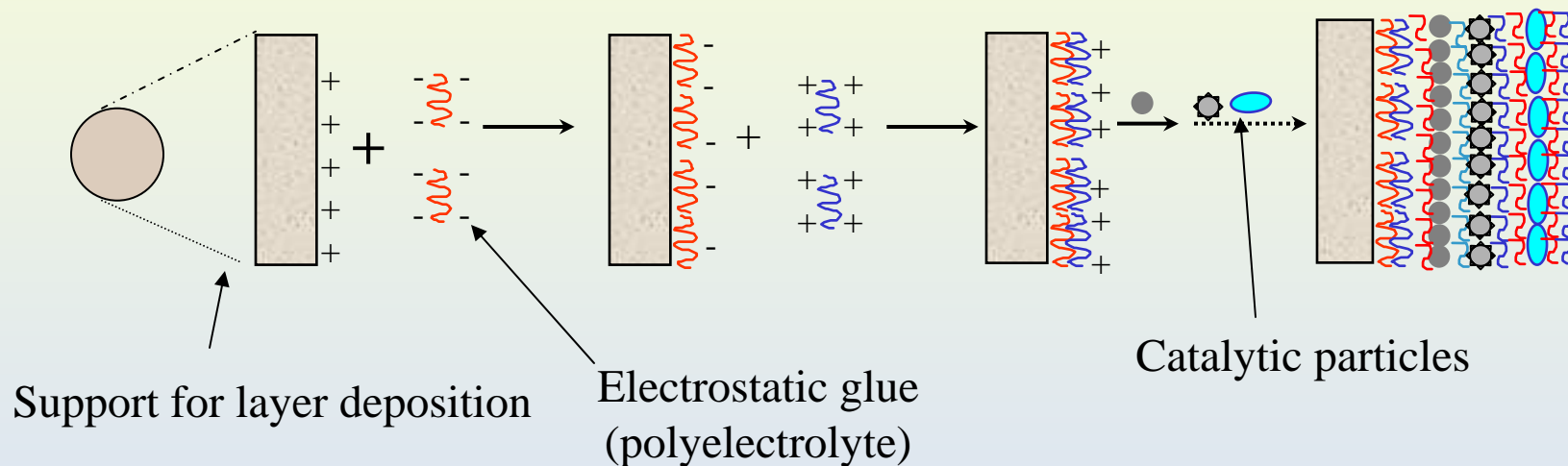
**Protect personnel and the environment** from chemical and biological agents, and toxins produced during their degradation.



Single System  $\Rightarrow$  Multi-protection

# MULTIFUNCTIONAL MULTILAYER FABRICATION

Layers are assembled by *complementary association of macromolecules* on surfaces varying in size, shape and texture



Fabrication Involves Water based Chemistry and Proven Film Deposition Techniques

- Dipping
- Spraying
- Spin coating

**Automation Makes the Film Fabrication Cost Effective**

# CHEMECAL AGENT PASSIVATION: Components and Scheme

## CATALYSTS

Organophosphorous Hydrolase (1) OPH

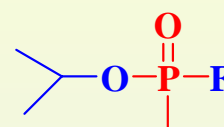
Organophosphoric acid anhydrolase (1) OPAA

## SUBSTRATES

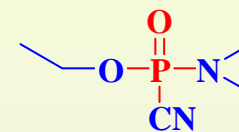
Cloth: Cotton, Glass

Beads: Polycyclodextrins

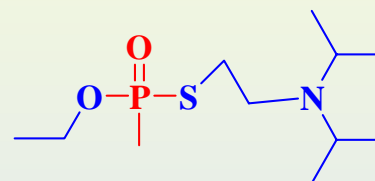
## NERVE AGENTS/ PESTIIDES



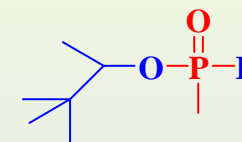
Sarin (GB)



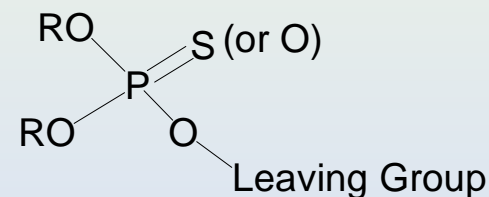
Tabun (GA)



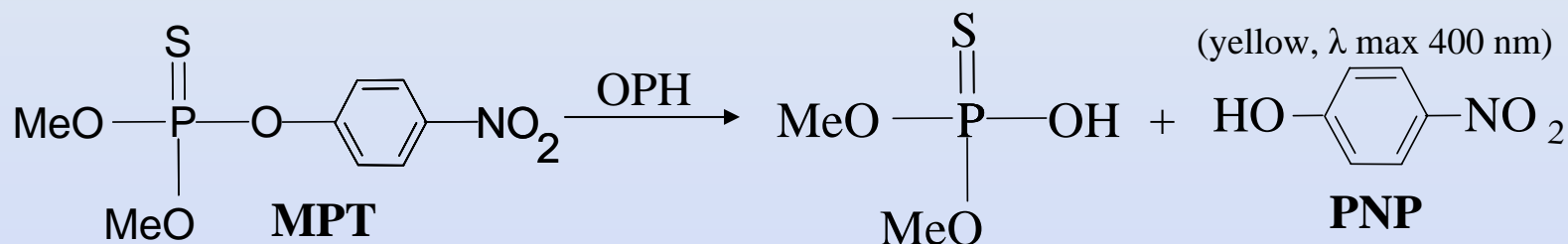
VX



Soman (GD )



**Methyl parathion (MPT) hydrolysis for activity assays:**





## NOVEL CAPABILITIES DEMONSTRATED

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- Stability of Enzymes in Multilayers
- Stability of Multilayers in Working Environment
- Control over Enzyme Loading in Multilayers
- Enzyme Performance on Various Supports
- Enzyme Activity Independent of Solvent, pH, and Temperature

# UTILITY OF MULTIFUNCTIONAL COATINGS

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## 1. Environmental Protection:

### *Support - Beads*

- Water filters
- Air filters (● Small rooms; ● masks)

## 2. Individual Protection:

### *Support - Cloth*

- Full body aprons
- Easy-breath masks

## 3. Surface Protection:

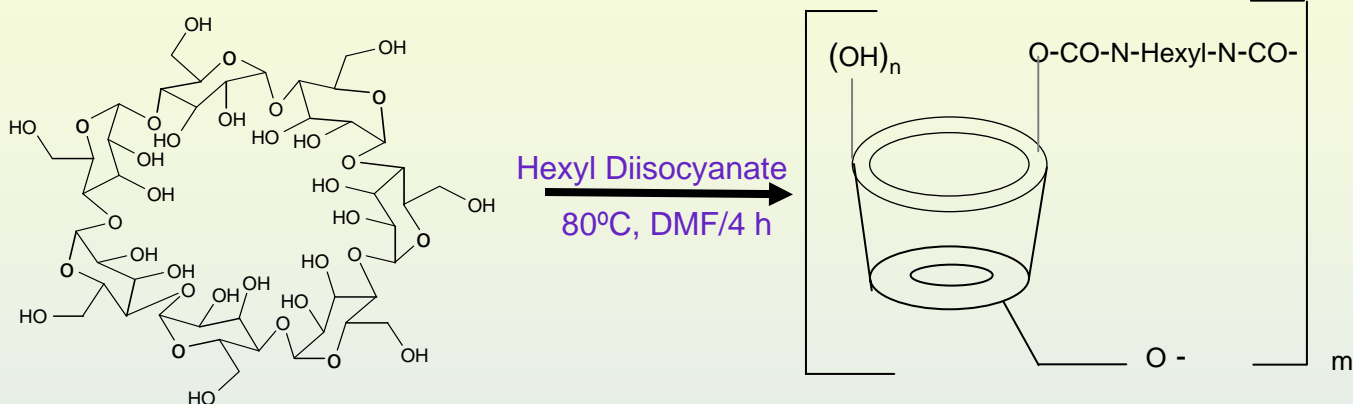
- Appliqué
- Paper Towel/Wipes

The application dictates the nature of the support

# ENVIRONMENTAL PROTECTION: Poly- $\beta$ -Cyclodextrin

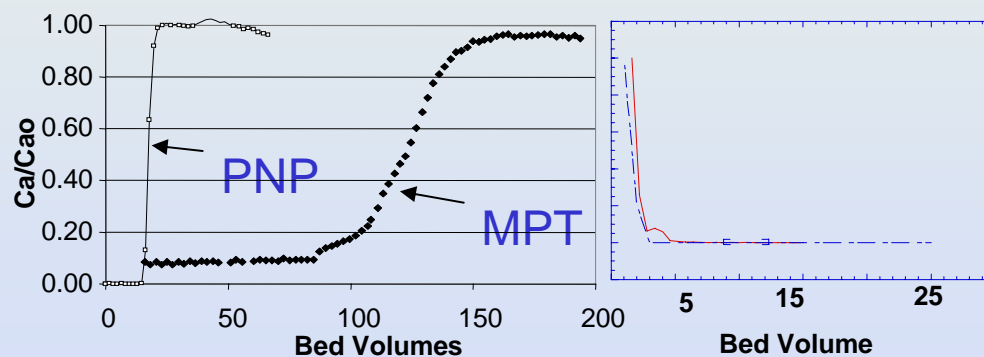
## Substrate for Multilayer Assemblies

System:



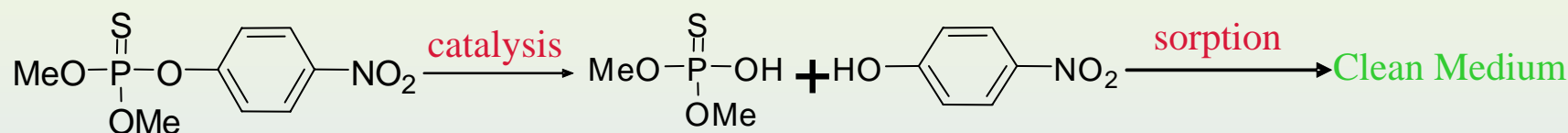
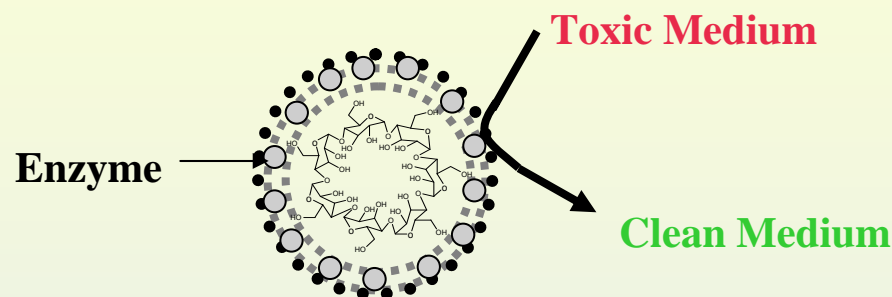
### Features

- surface area: 10.2 m<sup>2</sup>/g
- A total pore volume : 0.06 cm<sup>3</sup> /g
- Insoluble in most organic solvents
- Inert to acidic, basic media and
- 4-Times lighter than glass beads
- Capture toxins such as pNP and MPT



# ENZYME COATED POLY- $\beta$ -CYCLODEXTRIN BEADS

Sequence: PCD-BPEIH<sub>2</sub>O(pH 8.6)-OPHBTP(pH 8.6)-BPEIBTP(pH 8.6)



## Catalytic Activity of OPH-PCD

### *Environment*

Ambient condition(23 °C)

Low temperature (4 °C)

Methanol-2h

Acetone 2h

Salt Stress-NaCl (2M)-2 h

Tap water for 24 h

Water (pH 6.6)

### *Initial velocity (Vo)*

$1.9 \times 10^{-7}$  M/sec

$1.4 \times 10^{-7}$  M/sec

$6.4 \times 10^{-9}$  M/sec

$1.8 \times 10^{-8}$  M/sec

$9.6 \times 10^{-9}$  M/sec

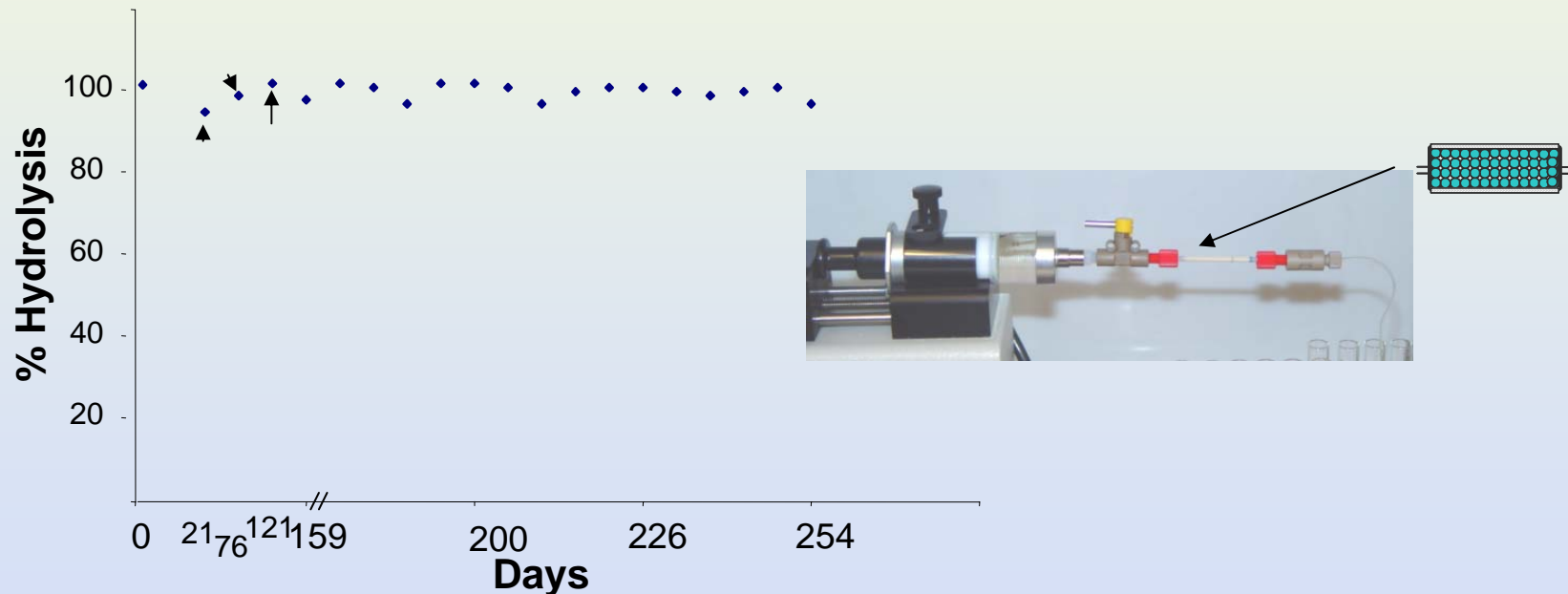
$1.1 \times 10^{-7}$  M/sec

$3.6 \times 10^{-7}$  M/sec

# FILTERS FOR ENVIRONMENTAL PROTECTION: Results

## Self-cleaning Filter Using OPH Coated Polycyclodextrin Beads:

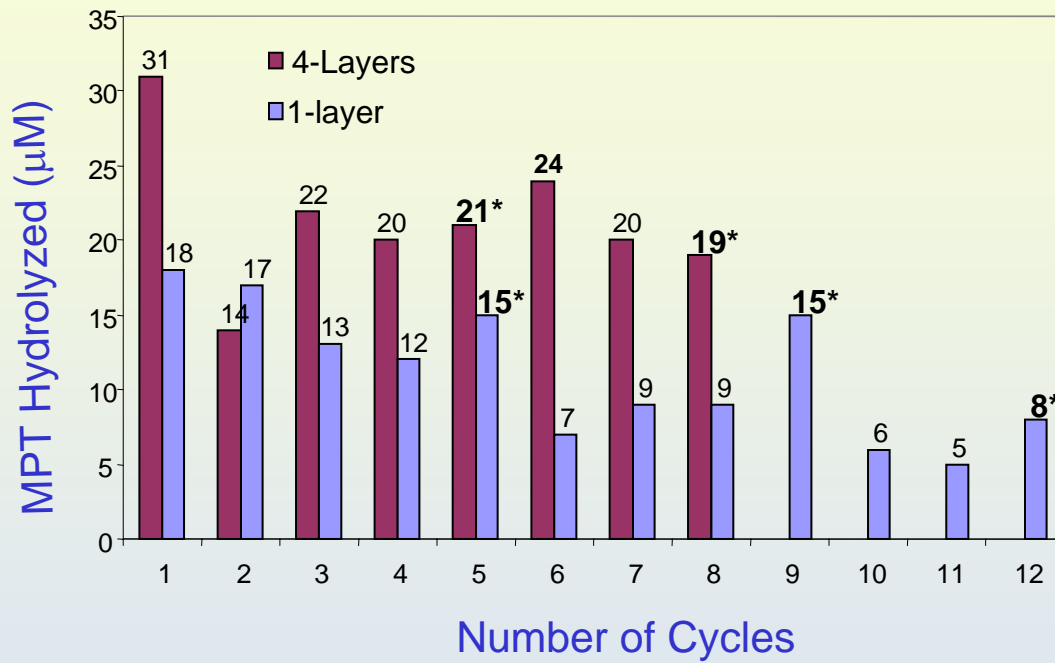
- Degrades 99+%, 100  $\mu$ M MPT at a flow rate equaling 1.9 min column resident time
- 32 mg MPT was degraded by 23 mg OPH/PCD beads  $\equiv$  *1 g Enzyme degraded 177 g Pesticide MPT*
- Sustained hydrolytic activity for 250 Days demonstrated



*US Patent Pending (Applications # 10/750,637; December 23.2003)*

# SELF-CLEANING FIBERGLASS: Results

Sequence: Cloth-BPEI(H<sub>2</sub>O)-OPH/BTP-BPEI/BTP-(PSS-BPEI(H<sub>2</sub>O)-OPH/BTP-BPEI/BTP)<sub>3</sub>



## MPT Hydrolysis capacity

56mg /g cloth (4-Layers in 2-week)

44 mg /g cloth (1-Layer in 3-weeks)

*\* Activity measured after storing the cloth at 4 °C for the weekend*

## Results Demonstrated:

- Retention of enzyme activity
- Resistance to washing cycles
- Reusability

# OPH IN MULTILAYERS ON KNITTED FABRIC



Both, cotton string coated with OPH (1-Layer) and the cloth knitted from the OPH-coated string showed identical activity: ~80% MPT (2mL, 100  $\mu$ M) was hydrolyzed within 5 minutes.

***Mechanical Stability Demonstrated***

**Cost to Cover 1 Enzyme layer on 100 m<sup>2</sup> Fabric  $\leq$  \$ 5.00**

US Patent Pending ( Applications # 10/849,621, May 20, 2004).

## CONCLUSIONS

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Proof-of-Principle for the Protection of Individuals and the Environment from chemical agents is established

- \* Light weight, reusable fabrics with mechanically stable coatings
- \* Filters for decontamination of water supplies
- \* Sustained catalytic activity independent of solvent, buffer or temperature



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